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July 21, 1995

William F. Caton
Acting Secretary
Federal Communications Commission
1919 M Street, N.W., Room 222
Washington, D.C. 20554

DOCKET FILE COPY ORIGINAL

Re: RM-8643

Dear Mr. Caton:

The above-referenced proceeding involves a Petition for Rule Making Regarding a Plan for Sharing the Costs of Microwave Relocation ("Petition") filed by Pacific Bell Mobile Services ("PBMS"). While the pleading cycle on the Petition is complete, the Fixed Point-to-Point Communications Section, Network Equipment Division of the Telecommunications Industry Association ("TIA"), wants to clarify certain statements in the record of this proceeding involving its Bulletin 10-F.

TIA is the principal industry association representing fixed point-to-point microwave radio manufacturers. TIA members serve, among others, companies, including telephone carriers, utilities, railroads, state and local governments, and cellular carriers, licensed by the Commission to use private and common carrier bands for provision of important and essential telecommunications services.

In 1994, TIA's Committee TR14.11, which I chair, adopted the "Telecommunications Systems Bulletin No. 10-F, Interference Criteria for Microwave Systems." In Bulletin 10-F, TIA prescribes standards for implementing the new fixed point-to-point microwave radio channel plans for the bands above 3 GHz and for establishing criteria regarding 2 GHz band PCS-to-microwave interference protection. The standards adopted and incorporated in Bulletin 10-F were developed based upon a broad-based industry consensus, which included frequency coordinators, microwave users, microwave manufacturers, PCS manufacturers, PCS providers, and representatives from UTAM, PCIA, and the Commission.

Unfortunately, two parties to the above-referenced rulemaking, Cox Enterprises, Inc. ("Cox") and Southwestern Bell Mobile Systems, Inc. ("SBMS"), mischaracterized the scope of Bulletin 10-F. Contrary to their comments, as demonstrated below, and in the attached excerpts from Bulletin 10-F, TIA has developed the industry standard for determining PCS-to-microwave interference.

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In its comments at page 3, Cox makes several incorrect statements regarding the scope of Bulletin 10-F, and in its reply comments at page 6, SBMS concurs with these statements. First, Cox states that "Bulletin 10-F contains microwave-to-microwave interference standards that do not lend themselves directly to assessing PCS-to-microwave interference." Cox is incorrect because Bulletin 10-F, Annex F, details the methods and procedures to be used for coordination of PCS and fixed microwave receivers. Second, Cox states that "Bulletin 10-F simply does not address, nor is it designed to assess, adjacent channel interference." This statement also is incorrect, as in Annex A of Bulletin 10-F, TIA describes, in detail, adjacent channel interference criteria (in particular, see Section A-12). Finally, Cox states that Bulletin 10-F "does not consider differences in terrain." In fact, TIA's Bulletin 10-F, Annex F at Section F-4.4.5, clearly addresses such terrain differences.

TIA is filing this letter to make sure that the record is accurate. If representatives of either Cox or SBMS wish to contact me at 214-996-5372, I would be happy to discuss this matter further.

Respectfully,

Phil Salas

Phil Salas
Chairman, TR14.11

cc: All parties of record

221825/gw03

TSB10-F

TIA/EIA TELECOMMUNICATIONS SYSTEMS BULLETIN

Interference Criteria for Microwave Systems

TSB10-F

(Revision of TSB10-E)

JUNE 1994

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Representing the telecommunications industry in association with the Electronic Industries Association

Annex A

Methods for Computing the Interference Objectives of FM-FDM Receivers

A-1 Introduction

Interference criteria are expressed as the ratio of the desired signal power to the interfering signal power. This ratio is called the carrier-to-interference (C/I) ratio. The C/I ratio at the receiver input is required to be greater than or equal to the C/I objective to achieve the baseband signal-to-interference objective. The C/I objective is used to determine how much radio-frequency (RF) interference one receiver can tolerate in the presence of other radio systems that operate in the same frequency band (co-channel, adjacent channel and semi-adjacent channel). It is specified in terms of maximum allowable power per exposure in the noisiest baseband channel of a multichannel telephone system. A lower C/I objective indicates a higher tolerance of the receiver for a given interference source.

For a given frequency separation between the carrier frequencies of the desired signal and the interfering signal, a C/I ratio corresponding to the baseband signal-to-interference objective can be computed for each baseband channel. The baseband channel which produces the least C/I ratio is the noisiest baseband channel. Its C/I ratio is called the C/I objective of the FM-FDM receiver at that particular frequency separation. This Annex describes the method for computing interference objectives of an FM-FDM receivers.

A-2 Pre-emphasis and De-emphasis

Because of the "triangular noise" characteristics of all FM receivers, the power spectral density of thermal noise and interference at the receiver output increases rapidly with baseband frequency. As a result, the S/N (signal-to-noise) and S/I (signal-to-interference) ratios fall off appreciably at higher baseband frequencies.

One approach to the efficient utilization of the allocated frequency band is based on the use of pre-emphasis in the FM transmitter and corresponding de-emphasis in the FM receiver. In this method, the high-frequency baseband deviation (level) is increased to equalize noise performance. At the FM receiver output, the distorted baseband signal is restored by de-emphasizing the high-frequency components. The pre-emphasis characteristic of an FM-FDM transmitter is determined by the following transfer function:[1]

$$|H_{pe}(f)|^2 = 0.4 + 1.35\left(\frac{f}{f_{max}}\right)^2 + 0.75\left(\frac{f}{f_{max}}\right)^4, \quad f_{min} \le f \le f_{max} \tag{A-1}$$

where f_{min} is the minimum baseband channel frequency and f_{max} is the maximum baseband channel frequency.

De-emphasis of an FM-FDM receiver has a transfer function that is equal to the inverse of the pre-emphasis filter transfer function. That is,

$$|H_{de}(f)|^2 = \frac{1}{|H_{pe}(f)|^2} \tag{A-2}$$

[1] "Annex 1: Calculation methods for the interference of FDM-FM systems", *Recommendation 766 – Methods for determining the effects of interference on the performance and the availability of terrestrial radio-relay systems and systems in the fixed-satellite service*, ITU-R, Geneva, 1992.

A-3 FM-FDM Interfering Signals

The power spectral density (normalized to unity power and centered on the carrier frequency) of an FM-FDM signal is determined by the following equation:[2]

$$P(f) = e^{-a}\left[\delta(f) + \sum_{n=1}^{\infty} \frac{1}{n!} S(f)\binom{n}{*} S(f)\right] \tag{A-3}$$

where:

- $S(f) = \dfrac{\Delta F^2 |H(f)|^2}{2f^2(f_{max} - f_{min})}$, $f_{min} \le |f| \le f_{max}$; ΔF is the total rms deviation; H(f) = H_{pe}(f) if the transmit baseband is pre-emphasized, and H(f) = 1 if the transmit baseband is not pre-emphasized.

- $a = \int_{f_{min}}^{f_{max}} 2S(f)df$

- $S(f)\binom{n}{*}S(f)$ denotes the convolution of the function S(f) by itself n times.

For example, $S(f)\binom{1}{*}S(f) = S(f)$, $S(f)\binom{2}{*}S(f) = S(f) * S(f)$

$S(f)\binom{3}{*}S(f) = S(f) * S(f) * S(f)$, etc. ("*" denotes the convolution operation.)

The low-order (small n) terms contribute relatively more to the central region of the power spectral density ; the higher order terms contribute relatively more to the tails. Therefore, in making the spectral calculations, it is practical to restrict the number of convolutions to a finite number so that the error resulting from this approximation is small in the frequency range of interest.

A-4 Digital Interfering Signals

Note: Where specific information does not exist, the power spectral density of the digital interfering

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[2] Equation 22, Annex 1, *Recommendation 766*, ITU-R, Geneva, 1992.

C. C. Ferris, "Spectral Characteristics of FM-FDM Signals", *IEEE Trans. Commun.*, vol. COM-16, pp. 233-238, April 1968.

signal shall be assumed to fill the relevant FCC mask.

Digital signals are classified by the modulation techniques that are imposed on them. In addition, the time duration of a bit controls the signal time duration T_s and the signal bandwidth. When k bits of information are embedded in a signal waveform during a signal time duration T_s, there are a total of $M=2^k$ possible signal waveforms that can be transmitted. This technique is called M-ary modulation in general or binary modulation when $M=2$. A radio signal can be digitally modulated in three different ways: phase modulation, amplitude modulation or frequency modulation. The power spectral densities (normalized to unity power and centered on the carrier frequency) are listed below for some commonly used modulation techniques.[3]

1. M-ary Phase-Shift-Key (MPSK) modulated signal:

$$P(f) = T_s\left(\frac{\sin(\pi f T_s)}{\pi f T_s}\right)^2 \tag{A-4}$$

2. Quadrature-Amplitude-Modulation (QAM) signal:

$$P(f) = T_s\left(\frac{\sin(\pi f T_s)}{\pi f T_s}\right)^2 \tag{A-5}$$

3. Minimum-shift-key (MSK) frequency-modulated signal:

$$P(f) = \frac{4T_s(1+\cos(2\pi f T_s))}{\pi^2(1-4f^2T_s^2)^2} \tag{A-6}$$

The signal time duration T_s is normally provided by the radio equipment manufacturer. It should be noted that the "roll off" characteristic of a transmitter filter may be an important factor in determining the power spectral density. It is also provided by the radio equipment manufacturer.

A-5 Interference Reduction Factor and Carrier-to-Interference Ratios

The interference reduction factor (IRF) is used to convert the baseband signal-to-interference ratio (SIR) of an FM-FDM receiver to its carrier-to-interference (C/I) ratio. The IRF is determined by the characteristics of the FM-FDM receiver and the normalized power spectral densities of the desired signal and the interfering signal. It also depends on the baseband channel frequency f_r and the frequency separation f_s between the carrier frequencies of the desired signal and the interfering signal. The interfering signal can be either an analog signal or a digitally modulated signal. The interference reduction factor of an FM-FDM receiver is expressed as:

$$IRF(f_r,f_s) = \frac{2\Delta F^2}{f_r^2(f_{max}-f_{min})D(f_r,f_s)\,|H(f_r)|^2} \tag{A-7}$$

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[3] Equations 36a to 36d, Annex 1, *Recommendation 766*, ITU-R, Geneva, 1992.

where

- $D(f_r, f_s) = PSD_w * PSD_i(f_s - f_r) + PSD_w * PSD_i(f_s + f_r)$ and "*" denotes the convolution operation; $PSD_w(f)$ and $PSD_i(f)$ are the power spectral densities of the desired signal and the interfering signal, respectively, and they are assumed to be normalized to unity power and centered on the carrier frequency.

- $H(f_r) = H_{de}(f_r)$ for an FM receiver with de-emphasis filter, and $H(f_r)=1$ for an FM receiver without de-emphasis filter.

The relationship between the baseband SIR and the C/I ratio of an FM-FDM receiver involves the IRF and it is expressed as follows:[4]

$$C/I(f_r, f_s)(dB) = SIR(dB) - IRF(f_r, f_s)(dB) \qquad \text{(A-8)}$$

It is observed that when the IRF is equal to 0 dB, the C/I is equivalent to the baseband SIR; however, when the IRF is not equal to 0 dB, the C/I is equal to the baseband SIR, adjusted by the IRF. The SIR is usually predetermined based on performance considerations or sometimes mandated by regulations.

A-6 Carrier-to-Interference Objective

For a given baseband signal-to-interference objective SIR_0, the carrier-to-interference objective $(C/I)_0(f_s)$ at each frequency separation f_s is defined to be the C/I ratio produced by the noisiest baseband channel corresponding to the baseband signal-to-interference objective SIR_0, that is

$$(C/I)_0(f_s) = \max_{f_{min} \le f_r \le f_{max}} \{SIR_0 - IRF(f_r, f_s)\} \qquad \text{(A-9)}$$

The interference reduction factor $IRF(f_r, f_s)$ is computed using Equation A-7 in Section A-5. The baseband signal-to-interference objectives SIR_0 is computed as follows:

1. SIR_0 (in dB) = X (in dBm0) - P (in dBm0)

   where:

   X = per-channel load (average talker power)
   P = per-hop baseband interference power objective

2. The per-channel load is regulated by *FCC Rules and Regulations* §2.203 (see Section 2.2).

3. The system baseband noise power objective is 250 pWp0 (see Section 2.5.2) and may be broken into tandem per-hop interference power objectives based on the length "L" and/or the number of hops "N" of the system.

[4] Equation 1, Annex 1, *Recommendation 766*, ITU-R, Geneva, 1992.

a. If "L" is greater than 400 km (long haul), the per-hop baseband interference power objective (in pWp0) is

$$\max\ \{5,\ 25 \times 10^{-\left[1.3\,Log\left(\frac{L}{400}\right)\right]}\}$$

b. If "L" is less than or equal to 400 km (short haul), the per-hop baseband interference power objective (in pWp0) is

$$\max\ \{25,\ 250\ /\ n\}$$

If the interfering signal is an FM-FDM signal and the baseband channel frequency f_r is equal to the frequency separation f_s (*i.e.*, the baseband channel with frequency f_r is corrupted by intercarrier beat interference), the per-hop baseband interference power objective is 50 pWp0.

4. The interference power objective is converted to dBm0 from pWp0 by using the relation:

$$dBm0 \ = \ 10\log(pWp0) - 87.5,\ \ flat,\ 3.1\ kHz\ \ bandwidth$$

A-7 Filter Selectivity

Note: for the purpose of frequency coordination, when the filter selectivity is not known, 0 dB shall be used.

In an FM-FDM system, the IF filter is designed so that it does not change the shape of the power spectral density of the desired signal significantly. However, the power spectral density of the interfering signal is reduced by this filter when the frequency separation between the carrier frequencies of the desired signal and the interfering signal is large (adjacent channels). The C/I objective in Equation A-9 can be re-derived to take the effect of IF filtering into account. This leads to the following equation:

$$(C/I)_0(f_s) \ = \ \max_{f_{min} \le f_r \le f_{max}} \{SIR_0 - IRF(f_r, f_s) - S_e(f_s)\} \qquad \text{(A-10)}$$

The factor $S_e(f_s)$ is called the filter selectivity of the receiver and it is computed from the power spectral density P(f) of the interfering signal and the transfer function G(f) of the IF filter by the following equation

$$S_e(f_s) \ = \ -10\log\left(\frac{\int P(f-f_s)\,|\,G(f)\,|^2\,df}{\int P(f-f_s)\,df}\right) \qquad \text{(A-11)}$$

where the integrals are taken over the frequency interval that contains at least 99 percent of the power of the interfering signal.

The filter transfer function G(f) of the IF filter is provided by the radio equipment manufacturer. It should be noted that the filter selectivity is negligible when the frequency separation f_s is small (co-channel) and, therefore, can be ignored in the C/I objective calculation for narrowband co-channel interferences. On the other hand, it can be a dominant factor in the C/I objective calculation for wideband or for adjacent-channel interferences.

A-8 Instability of the Carrier Frequency

The carrier frequencies of the desired signal and the interfering signal are not always stable. They can be drifted to frequencies that are larger or smaller than the intended frequencies. The amount of frequency drift is small for newer equipments but its effect on the calculation of the C/I objective cannot be ignored. If we assume that $\pm\epsilon_w$ and $\pm\epsilon_i$ are the maximum frequency drifts of the desired signal and the interfering signal, respectively, then the frequency separation f_s between those two signals is drifted from the intended frequency separation f_0 by an amount that can be as large as $\epsilon_i+\epsilon_w$. Precisely, the frequency separation f_s and the intended frequency separation f_0 are related by the following inequalities

$$\max\{0, f_o-(\epsilon_i+\epsilon_w)\} \le f_s \le f_0+(\epsilon_i+\epsilon_w) \tag{A-12}$$

The C/I objective at the intended frequency separation f_0 is now defined to be the maximum C/I objective over the range of frequency separation that satisfies the inequalities in Equation A-12. This definition can be expressed mathematically as follows:

$$(C/I)_0(f_s) = \max_{f_s} \max_{f_r} \{SIR_0 - IRF(f_r, f_s) - S_e(f_s)\} \tag{A-13}$$

where f_s satisfies Equation A-12 and f_r is between f_{min} and f_{max}.

A-9 Minimum C/I Objective

Equation A-8 provides a relationship between the C/I ratio and the baseband signal-to-interference ratio which is accurate when the C/I ratio is at least 10 dB. Therefore, the minimum C/I objective shall be set at 10 dB. Given a minimum C/I objective, the maximum interference power that is allowed to enter an FM-FDM receiver can be determined from the receiver threshold R_t and the filter selectivity $S_e(f)$. The receiver threshold is defined as the carrier power level that produces a flat signal-to-thermal noise ratio of 30 dB in the noisiest VF channel of the receiver baseband. The receiver will mute automatically when the carrier power "C "is below the receiver threshold R_t.

When the link fade margin required for the desired performance (outage time) is limited by thermal noise, the maximum allowable interference power is determined from

$$\frac{R_t}{I}(dB) \geq 10 - S_e(f_s) \tag{A-14}$$

Or, equivalently, the maximum interference power is determined by

$$I_{max} = R_t + S_e(f_s) - 10 \tag{A-15}$$

where the filter selectivity $S_e(f_s)$ is in dB, R_t and I_{max} are in dBm.

When the desired availability is not thermally limited and baseband noise objectives are not the limiting criteria (see Section A-6), the maximum interference power is Equation A-15 is allowed to increase by F_α, the excess fade margin corresponding to a link outage (or % path reliability) objective. Equation A-15 now becomes

$$I_{max} = R_t + F_\alpha + S_e(f_s) - 10 \tag{A-16}$$

The technique for computing the required fade margin is outlined in Section 4.2.3.

A-10 Characteristics of FM-FDM Signals

The characteristics of some typical FM-FDM signals are tabulated in Table A-1.

Number of Channels	Per Channel Load (dBm0)	Per Channel RMS Deviation (kHz)	Total RMS Deviation (kHz)	Lowest Channel Frequency (kHz)	Highest Channel Frequency (kHz)	RF Bandwidth (MHz)
2400	-19.6	140	718	564	11,596	30
600	-15	140	610	60	2,540	10
300	-15	175	317	60	1,300	5
96	-15	47	104	12	408	1.6
48	-15	26	52	12	204	0.8

Table A-1 — FM-FDM Signal Characteristics

A-11 C/I Objective Curves

Note: The follow curves were derived from the equations in this Annex. These curves represent many typical cases. For cases not covered by these curves, or if greater resolution is required, refer to the equations directly. All the curves in this Section assume emphasized radios.

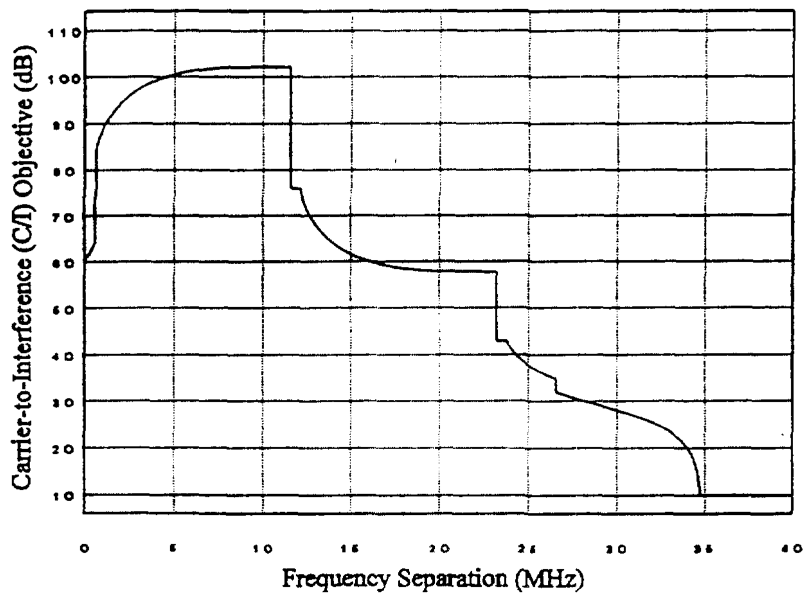

Figure A-1 **C/I objective (0 dB filter selectivity) of a 2,400-channel FM-FDM receiver subject to interference from a 2,400-channel FM-FDM signal**

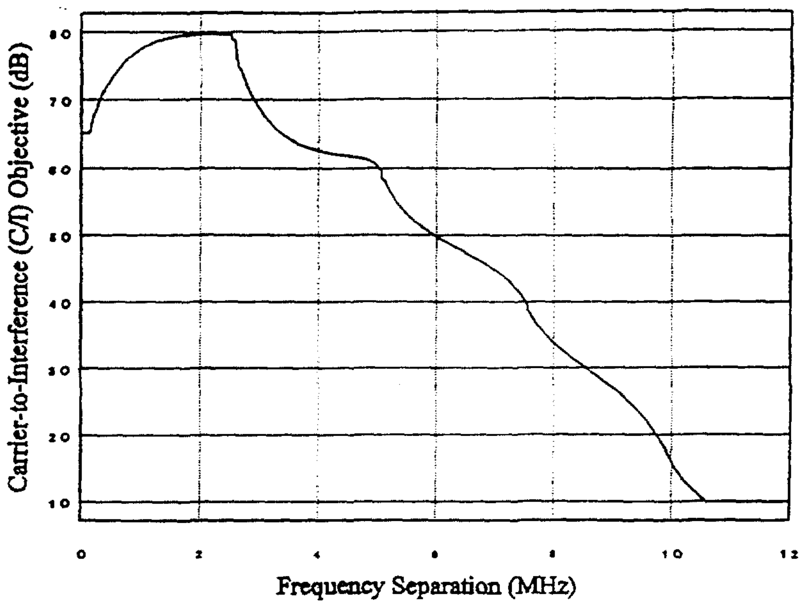

Figure A-2 C/I objective (0 dB filter selectivity) of a 600-channel FM-FDM receiver subject to interference from a 600-channel FM-FDM signal

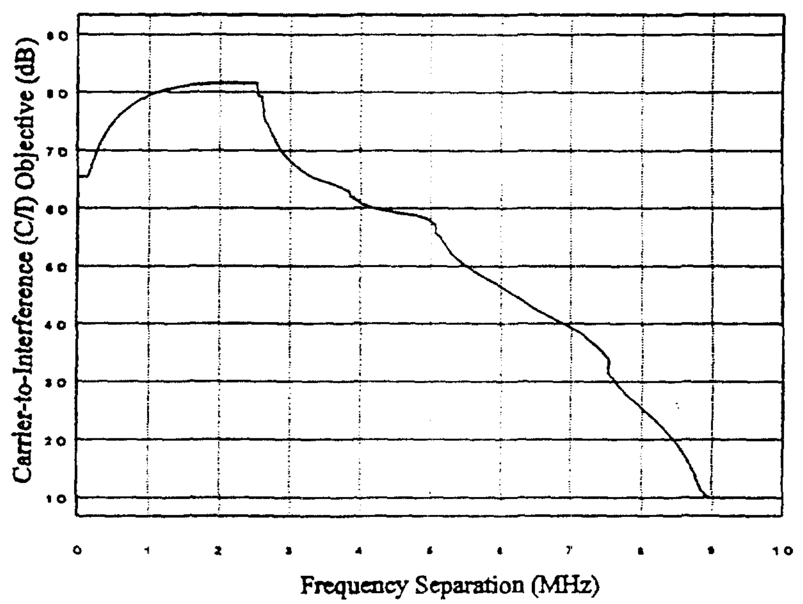

Figure A-3 C/I objective (0 dB filter selectivity) of a 600-channel FM-FDM receiver subject to interference from a 300-channel FM-FDM signal

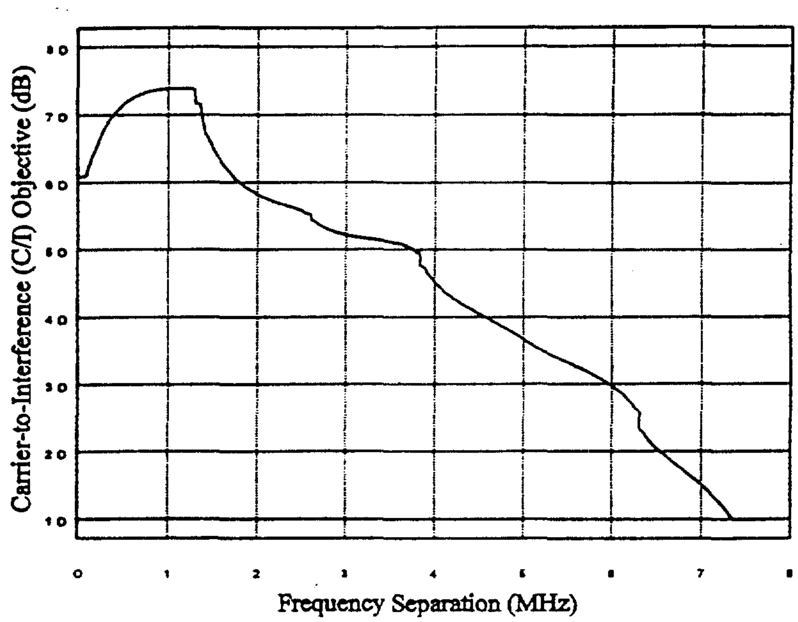

Figure A-4 C/I objective (0 dB filter selectivity) of a 300-channel FM-FDM receiver subject to interference from a 600-channel FM-FDM signal

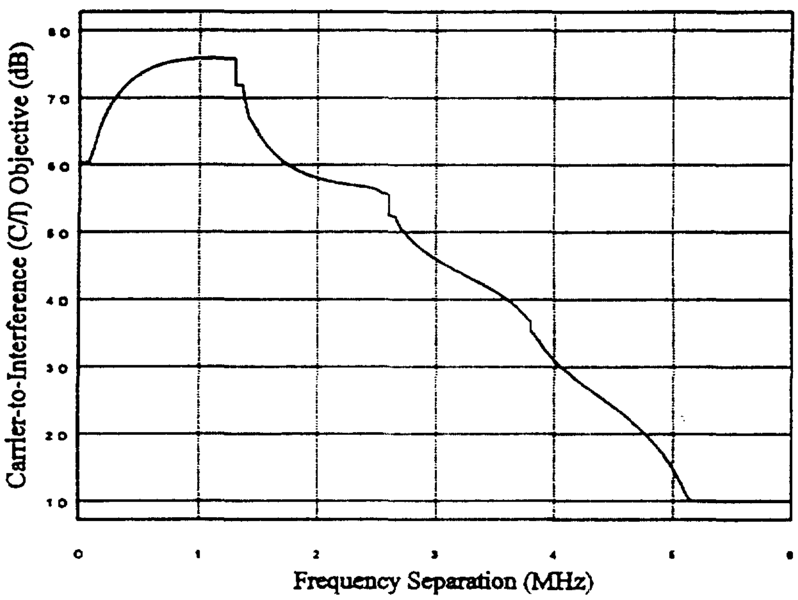

Figure A-5 C/I objective (0 dB filter selectivity) of a 300-channel FM-FDM receiver subject to interference from a 300-channel FM-FDM signal

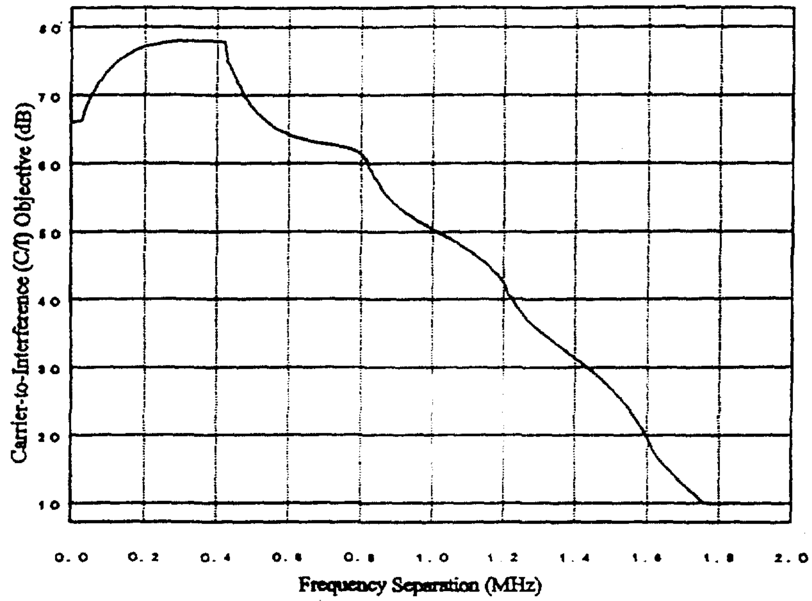

Figure A-6 **C/I objective (0 dB filter selectivity) of a 96-channel FM-FDM receiver subject to interference from a 96-channel FM-FDM signal**

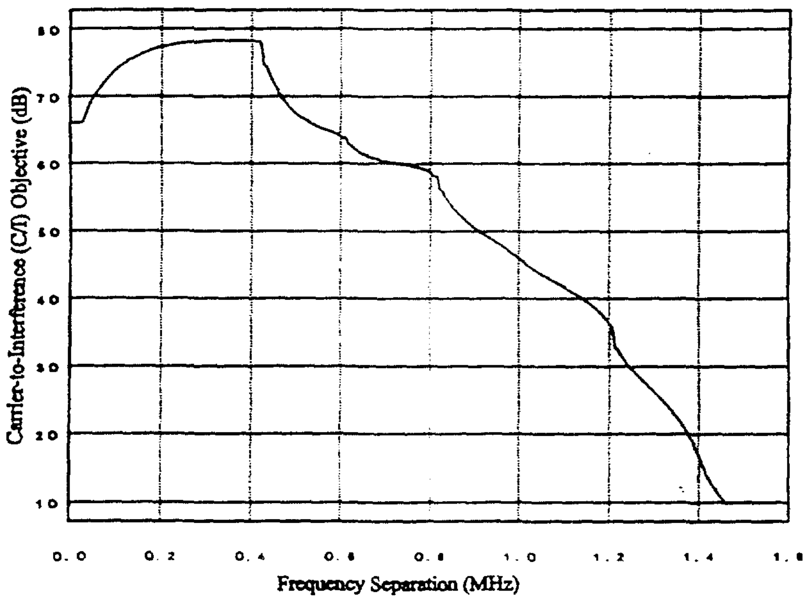

Figure A-7 **C/I objective (0 dB filter selectivity) of a 96-channel FM-FDM receiver subject to interference from a 48-channel FM-FDM signal**

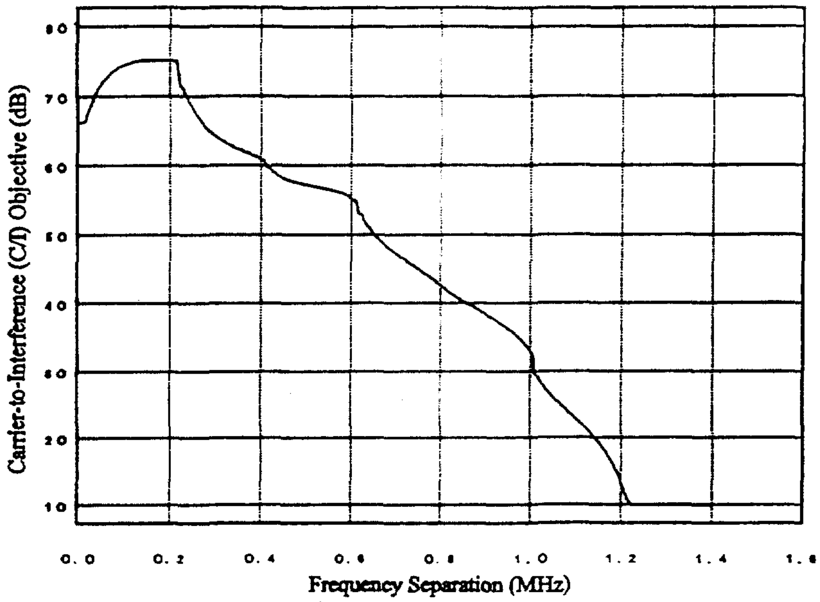

Figure A-8 C/I objective (0 dB filter selectivity) of a 48-channel FM-FDM receiver subject to interference from a 96-channel FM-FDM signal

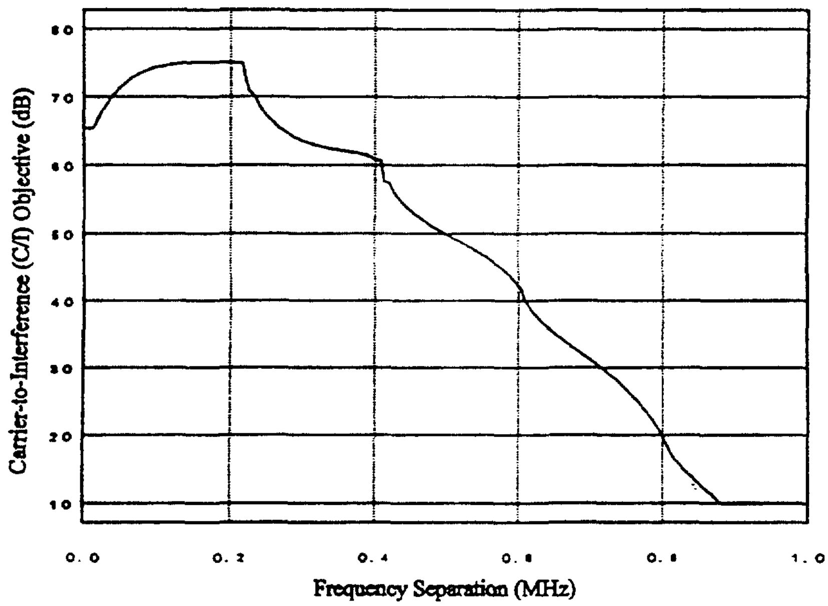

Figure A-9 C/I objective (0 dB filter selectivity) of a 48-channel FM-FDM receiver subject to interference from a 48-channel FM-FDM signal

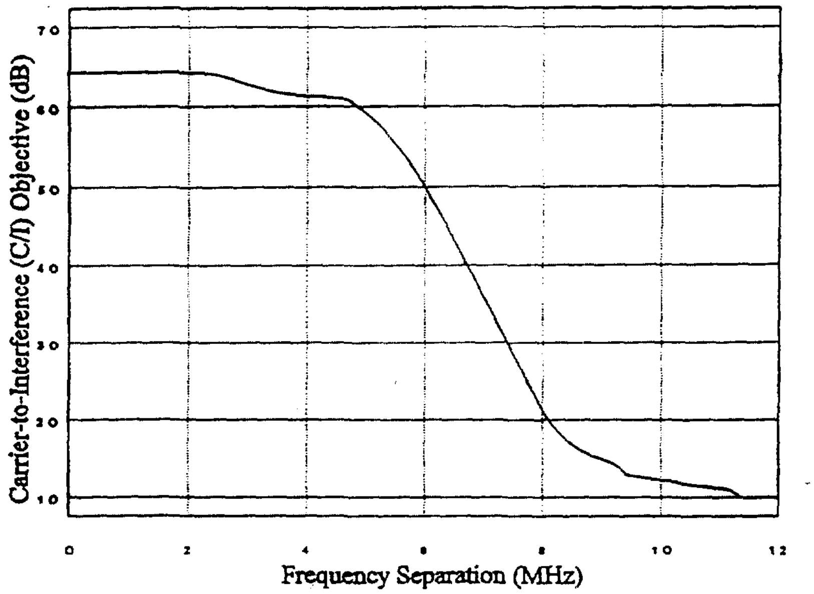

Figure A-10 C/I objective (0 dB filter selectivity) of a 300-channel FM-FDM receiver subject to interference from a single DS3 64-QAM digital signal

A-12 Adjacent Channel Noise

Adjacent channel noise is a complex function of desired and interfering signal emission and receiver filtering characteristics. The following examples are given for 300 and 600 FM-FDM receivers. The example spectrum emissions and FM receiver characteristics are diagrammed in Figure A-11. Caution is advised in the use of the PCS curves since PCS spectral characteristics are still evolving.

The 5 and 10 MHz filter responses represent typical FM receiver responses. The "sharp" filter represents the narrowest FM receiver filter expected to be found in threshold extension circuitry. All three filters are based upon actual receiver measurements. However, the filters are provided for illustration. Frequency coordination should use actual receiver characteristics.

Adjacent channel noise (calculated in accordance with Equation A-7 for the characteristics shown in Figure A-11) is displayed in Figures A-12 andA-13. The "sharp" filter noise results represent the limit of practical filters.

The PCS spectra are based on *FCC GEN Docket No. 90-314, Second Report and Order*, September 23, 1993. The following is an analysis leading to the emission characteristics used for these calculations.

A-12.1 Licensed PCS (FCC Part 24) coordination criteria

Transmit power, transmit spectrum emission, and channel bandwidth are currently undefined. Coordination criteria will be established when these criteria are available.

A-12.2 Unlicensed PCS (FCC Part 15) coordination criteria

The material presented in this section is a preliminary interpretation of current FCC rules (May 1994). The results may need to be revised after the measurement standards being developed in ANCI C63 committee becomes available.

Coordination criteria require a definition of emission spectrum power over a narrow measurement bandwidth (typically 3 kHz).

A-12.2.1 1910-1930 MHz unlicensed PCS sub-band

Two channel bandwidths for these sub-bands are defined: 1.25 MHz and 5.0 MHz. Transmit powers for these bandwidths are (*FCC Rules and Regulations* §15.319(c)) 112 mW and 224 mW respectively. Assuming equal spreading of transmit power over the available bandwidth, the transmit power measured in a 3 kHz measurement bandwidth relative to total transmit power (dBt) is -26.2 dBt and -32.2 dBt in the two channels respectively.

The transmit spectrum emissions (*FCC Rules and Regulations* §15.321 (d)) must be attenuated below the following limits referenced to 112 mW when measured in a bandwidth of 1% of the channel bandwidth:

Between channel edge and 1.25 MHz above or below the channel:	-40 dB
Between 1.25 MHz and 2.50 MHz above or below the channel:	-50 dB
Greater than 2.50 MHz above or below the channel:	-60 dB

The conversion factor from a 12.5 kHz and 50 kHz measurement bandwidth to 3 kHz measurement bandwidth is -6.2 dB and -12.2 dB respectively.

The conversion factor from a 112 mW power reference to a 224 mW reference is -3.0 dB.

From the above we may establish the following spectrum emission powers measured in a 3 kHz wide measurement bandwidth relative to total transmit power dBt.

Absolute Frequency (in MHz, relative to channel center frequency)			Transmitted Power (in 3 kHz measurement bandwidth)
0.000	to	0.625	-26.2 dBt
0.625	to	1.875	-46.2 dBt
1.875	to	3.125	-56.2 dBt
Greater than 3.125			-66.2 dBt

Table A-2 — 1.25 MHz Channel (0 dBt = 0.112 Watts Transmit Power)

Absolute Frequency (in MHz, relative to channel center frequency)			Transmitted Power (in 3 kHz measurement bandwidth)
0.000	to	2.500	-32.2 dBt
2.500	to	3.750	-55.2 dBt
3.750	to	5.000	-65.2 dBt
Greater than 5.000			-75.2 dBt

Table A-3 — 5.0 MHz Channel (0 dBt = 0.224 Watts Transmit Power)

A-12.2.2 1900 MHz to 1920 MHz unlicensed PCS sub-band

The channel bandwidth for this sub-band is 10.0 MHz. Transmit power for this sub-band is not defined. However, if we assume maximum power is limited in the same way as the other unlicensed sub-band (*i.e.*, *FCC Rules and Regulations* §15.319(c)), the maximum transmit power is 316 mW. Assuming this power is spread equally over the 10 MHz channel, the transmit power in a 3 kHz relative to total transmit power is -35.2 dBt.

The transmit spectrum emission limits (*FCC Rules and Regulations* §15.323 (d)) are exactly the same as those defining the other unlicensed sub-bands (*FCC Rules and Regulations* §15.321 (d)).

The conversion factors from a 100 kHz measurement bandwidth to a 3 kHz measurement bandwidth is -15.2 dB.

The conversion factor from a 112 mW reference power to a 316 mW reference power is -4.5 dB.

From the above, we may establish the following spectrum emission powers measured in a 3 kHz measurement bandwidth relative to total transmit power dBt.

Absolute Frequency (in MHz, relative to channel center frequency)			Transmitted Power (in 3 kHz measurement bandwidth)
0.000	to	5.000	-35.2 dBt
5.000	to	6.125	-59.7 dBt
6.125	to	7.250	-69.7 dBt
Greater than 7.250			-79.7 dBt

Table A-4 — 10.0 MHz Channel (0 dBt = 0.316 Watts Transmit Power)

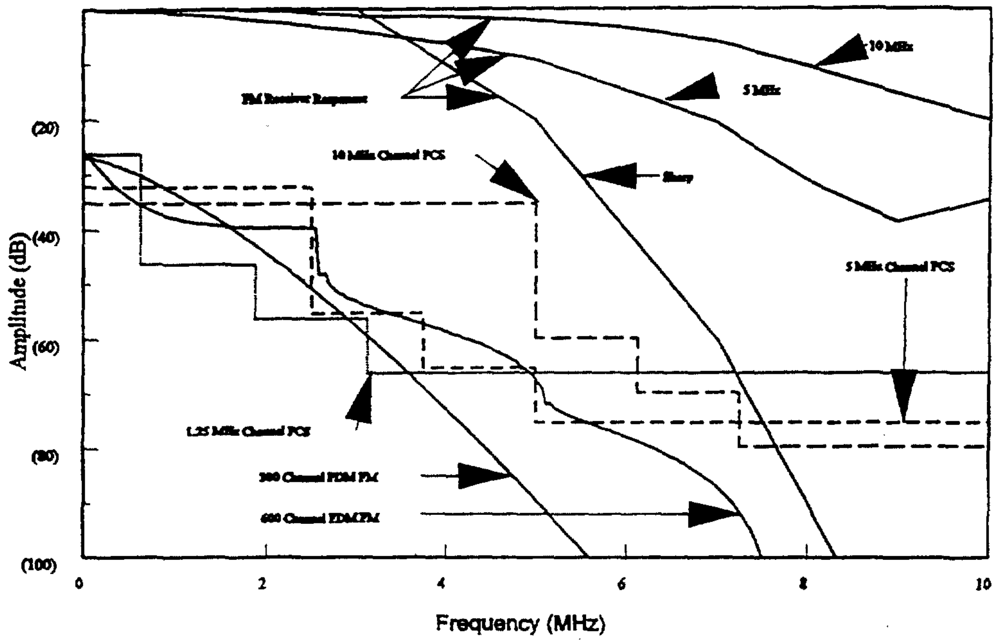

Figure A-11 **Spectrum Amplitude and FM Receiver Response (Spectrum Measurement Bandwidth = 3 kHz)**

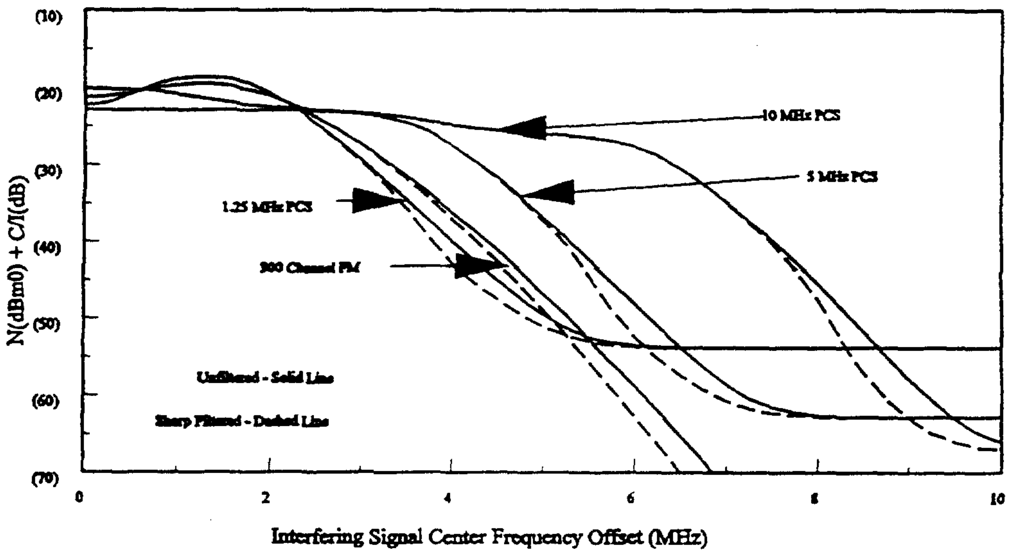

Figure A-12 **Adjacent Channel Noise (300 Channel FM Receiver with ITU-R Emphasis, 200 kHz and -15 dBm0 per channel parameters)**

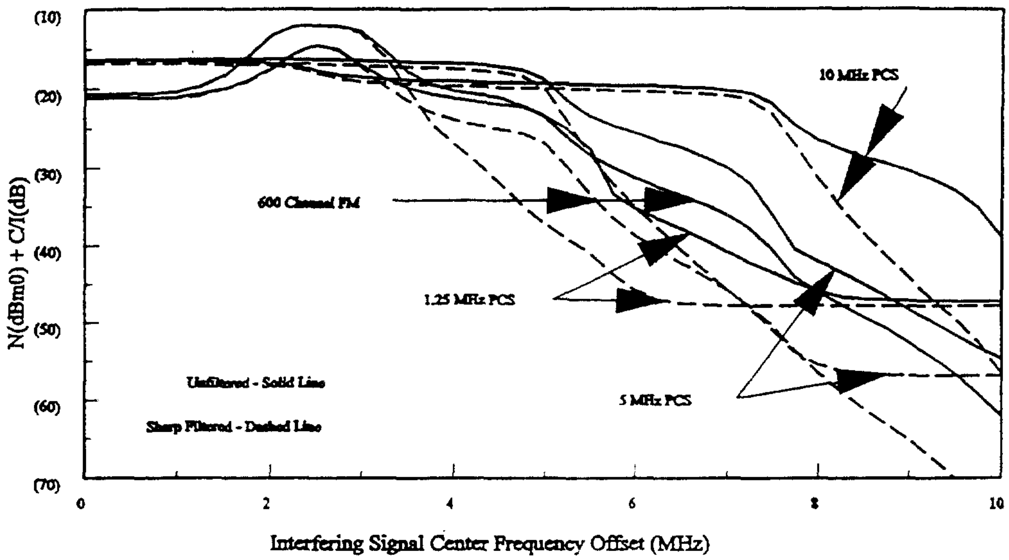

Figure A-13 Adjacent Channel Noise (600 Channel FM Receiver with ITU-R Emphasis, 140 kHz and -15 dBm0 per channel parameters)

A-13 FM Receiver Threshold, R_t

The receive signal level (RSL) which causes an FM receiver to have a 30 dB signal-to-noise (dBm0) ratio in the noisiest 3.1 kHz VF channel in the baseband is a function of receiver noise figure, per channel deviation, and measurement frequency. Tables A-2, A-3, and A-4 give values for R_t based on worst case frequency and various deviations and receiver noise figures. These tables assume an RSL and noise figure measured at the same receiver input point.

The above mentioned charts may be used to determine a value of desired signal power "C" such that the 30 dB S/N FM receiver threshold is not exceeded more than an acceptable period of time. The difference between "C" and the normal (unfaded) received signal level is fade margin. Path design tasks include calculating the 30 dB S/N threshold degradation due to adjacent channel interfering signals. This is accomplished using Equation A-15. This equation assumes that the interfering signal power has been reduced by the FM receiver's RF and, mainly, IF filtering circuits. For FM systems, signal power is dominated by the carrier only (sidebands are negligible) so the effective selectivity is merely the filter response at the carrier frequency. PCS and digital radio signal spectra is quite flat and broad without any distinct carrier. For these cases, effective selectivity is calculated using Equation A-11. Examples for filters and spectra defined in Figure A-11 are displayed in Figures A-14, A-15, and A-16. These filters are shown for illustration. Actual filter data should be used for frequency coordination.

Tables A-5, A-6 and A-7 are based upon the following formula:

$$
\begin{aligned}
\frac{S}{N}(dB) &= Signal\text{-}to\text{-}Noise\ Ratio,\ dB\ (flat\ or\ weighted) \\
&= -N,\ dBm0 \qquad\qquad \text{(A-17)} \\
&= +139.1 + RSL - NF + 20\log[d] \\
&\quad - 20\log[f] + E + CF
\end{aligned}
$$

S = reference test tone (0 dBm0 or 0 dBr)
N = average noise power in a 3.1 kHz telephone channel (dBm0)
N (dBm) = S (dBm) - S/N (dB)
RSL = received signal level (dBm)
NF = receiver noise figure at the RSL interface (dB)
d = per-channel RMS deviation caused by S (kHz)
f = baseband frequency of the telephone channel (kHz)
E = correction factor for pre-emphasis (dB)
= 0.0 dB for no emphasis

$$= 10\log\left[0.4 + 1.35\left(\frac{f}{f_{max}}\right)^2 + 0.75\left(\frac{f}{f_{max}}\right)^4\right], \quad (see\ Equation\ A-1)$$

f_{max} = Highest baseband channel frequency (kHz)

CF = correction factor for telephone channel weighting (dB)
= 0.0 dB for no (flat) weighting
= 2.0 dB for C-message weighting
= 2.5 dB for psophometric weighting

For a more detailed treatment of the above topics, see Chapter 3, Equation 3-92, and Chapter 11, Equation 11-231, of *Microwave Communication* by George Kizer, Iowa State University Press, 1990.

NF	System Without Emphasis				System With Emphasis			
	d=100	d=140	d=175	d=200	d=100	d=140	d=175	d=200
1	-86	-89	-91	-92	-90	-93	-95	-96
2	-85	-88	-90	-91	-89	-92	-94	-95
3	-84	-87	-89	-90	-88	-91	-93	-94
4	-83	-86	-88	-89	-87	-90	-92	-93
5	-82	-85	-87	-88	-86	-89	-91	-92
6	-81	-84	-86	-87	-85	-88	-90	-91
7	-80	-83	-85	-86	-84	-87	-89	-90
8	-79	-82	-84	-85	-83	-86	-88	-89
9	-78	-81	-83	-84	-82	-85	-87	-88
10	-77	-80	-82	-83	-81	-84	-86	-87
11	-76	-79	-81	-82	-80	-83	-85	-86
12	-75	-78	-80	-81	-79	-82	-84	-85
13	-74	-77	-79	-80	-78	-81	-83	-84
14	-73	-76	-78	-79	-77	-80	-82	-83
15	-72	-75	-77	-78	-76	-79	-81	-82

f_{max} = Top channel frequency (kHz)
NF = Noise figure (dB)
d = Per-channel RMS deviation (kHz)

Table A-5 300 Channel FM-FDM System — RSL (dBm) for 30 dB Top Channel S/N (f_{max} = 1,300 kHz)

NF	System Without Emphasis				System With Emphasis			
	d=100	d=140	d=175	d=200	d=100	d=140	d=175	d=200
1	-77	-80	-83	-86	-81	-84	-87	-90
2	-76	-79	-82	-85	-80	-83	-86	-89
3	-75	-78	-81	-84	-79	-82	-85	-88
4	-74	-77	-80	-83	-78	-81	-84	-87
5	-73	-76	-79	-82	-77	-80	-83	-86
6	-72	-75	-78	-81	-76	-79	-82	-85
7	-71	-74	-77	-80	-75	-78	-81	-84
8	-70	-73	-76	-79	-74	-77	-80	-83
9	-69	-72	-75	-78	-73	-76	-79	-82
10	-68	-71	-74	-77	-72	-75	-78	-81
11	-67	-70	-73	-76	-71	-74	-77	-80
12	-66	-69	-72	-75	-70	-73	-76	-79
13	-65	-68	-71	-74	-69	-72	-75	-78
14	-64	-67	-70	-73	-68	-71	-74	-77
15	-63	-66	-69	-72	-67	-70	-73	-76

f_{max} = Top channel frequency (kHz)
NF = Noise figure (dB)
d = Per-channel RMS deviation (kHz)

Table-6 **600 Channel FM-FDM System — RSL (dBm) for 30 dB Top Channel S/N (f_{max} = 2,540 kHz)**

NF	System Without Emphasis				System With Emphasis			
	d=100	d=140	d=175	d=200	d=100	d=140	d=175	d=200
1	-64	-67	-70	-73	-68	-71	-74	-77
2	-63	-66	-69	-72	-67	-70	-73	-76
3	-62	-65	-68	-71	-66	-69	-72	-75
4	-61	-64	-67	-70	-65	-68	-71	-74
5	-60	-63	-66	-69	-64	-67	-70	-73
6	-59	-62	-65	-68	-63	-66	-69	-72
7	-58	-61	-64	-67	-62	-65	-68	-71
8	-57	-60	-63	-66	-61	-64	-67	-70
9	-56	-59	-62	-65	-60	-63	-66	-69
10	-55	-58	-61	-64	-59	-62	-65	-68
11	-54	-57	-60	-63	-58	-61	-64	-67
12	-53	-56	-59	-62	-57	-60	-63	-66
13	-52	-55	-58	-61	-56	-59	-62	-65
14	-51	-54	-57	-60	-55	-58	-61	-64
15	-50	-53	-56	-59	-54	-57	-60	-63

f_{max} = Top channel frequency (kHz)
NF = Noise figure (dB)
d = Per-channel RMS deviation (kHz)

Table A-7 2400 Channel FM-FDM System — RSL (dBm) for 30 dB Top Channel S/N (f_{max} = 11,596 kHz)

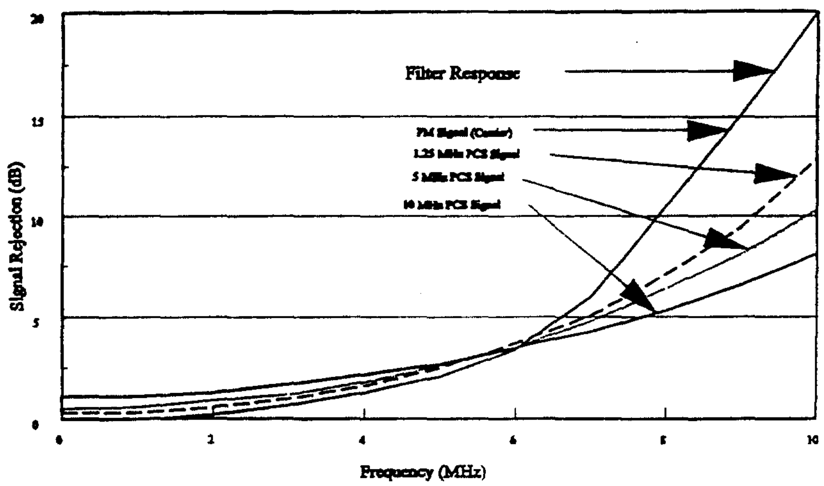

Figure A-14 Filter Selectivity Factor "Se" (10 MHz FM Receiver Filter)

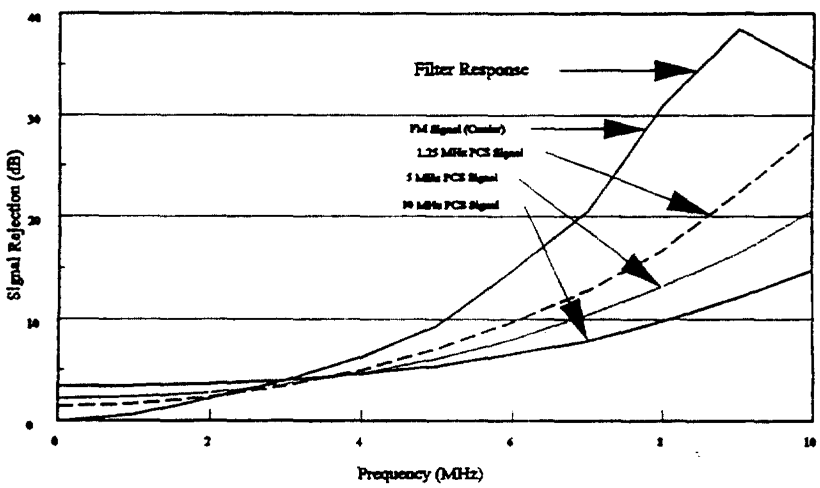

Figure A-15 Filter Selectivity Factor "Se" (5 MHz FM Receiver Filter)